

Claims

What is claimed is:

1. A method for diagnosing the possibility of disease in a body part, the method comprising

representing the body part with a grid having a plurality of finite elements;

obtaining a set of weights associated with a particular one of the plurality of finite elements using a model of the body part;

computing a diagnostic at the particular finite element, the diagnostic being a function of the set of weights, and a measured electrical property obtained with an electrode array; and

utilizing the diagnostic to diagnose the possibility of disease in the body part.

2. The method of claim 1, further comprising obtaining a baseline electrical property associated with the body part using the model thereof, wherein the diagnostic is a function of the baseline electrical property, the set of weights, and the measured electrical property obtained with the electrode array.

3. The system of claim 1, wherein the measured electrical property is conditioned to compute the diagnostic.

4. The method of claim 1, wherein the measured electrical property is an impedance.
5. The method of claim 1, wherein, in the step of representing, the grid is a two dimensional grid.
6. The method of claim 1, wherein, in the step of representing, the grid is a three dimensional grid.
7. The method of claim 2, wherein the baseline electrical property is obtained using a physical model of the body part.
8. The method of claim 2, wherein the baseline electrical property is obtained using a control subject.
9. The method of claim 2, wherein the baseline electrical property is obtained using a finite element method.
10. The method of claim 9, wherein the baseline electrical property is obtained by
 - obtaining a baseline voltage; and
 - using the baseline voltage to compute a baseline impedance.

11. The method of claim 10, wherein, in the step of obtaining a baseline electrical property, the model of the body part assumes a non-uniform resistivity.

12. The method of claim 1, further comprising
applying a plurality of electrodes to the body part; and

obtaining a measured electrical property of the body part with the plurality of electrodes.

13. The method of claim 12, wherein the step of applying includes
applying n_{CI} current injection electrode pairs on the body part, where n_{CI} is an integer greater than zero; and

applying n_{CI} voltage measurement electrode pairs on the body part, each of the current injection electrode pairs associated with one of the n_{CI} voltage measurement electrode pairs.

14. The method of claim 13, wherein the step of obtaining a measured electrical property includes

injecting a first current between a first pair of the n_{CI} current injection electrode pairs;

measuring the resultant voltage difference V_1^M between the voltage measurement electrode pair associated with the first current injection electrode pair;

repeating the preceding two steps of injecting and measuring with the other electrode pairs until all n_{CI} voltage differences, $\{V_1^M, V_2^M, \dots, V_{n_{CI}}^M\}$ are obtained; and

using the n_{CI} voltage differences to obtain associated measured impedances, $\{Z_1^M, Z_2^M, \dots, Z_{n_{CI}}^M\}$, where Z_j^M is the measured impedance obtained by using the j^{th} current injection electrode pair and the voltage measurement electrode pair associated therewith.

15. The method of claim 14, wherein, if the particular finite element is identified as the k^{th} finite element and the set of weights is denoted by $\{w_{1k}, w_{2k}, \dots, w_{n_{CI}k}\}$ where w_{ik} is the weight associated with the k^{th} finite element and i^{th} current injection electrode pair, then the step of obtaining a set of weights, , includes

using the model of the body part to obtain a set of current densities, $\{J_{1k}, J_{2k}, \dots, J_{n_{CI}k}\}$, where J_{ik} is the current density at the k^{th} finite element when current is injected between the i^{th} current injection electrode pair; and

obtaining the set of weights using the relation

$$w_{ik} = \frac{J_{ik}}{\sum_{j=1}^{n_{cl}} J_{jk}} .$$

16. The method of claim 15, wherein the step of obtaining a baseline electrical property includes

using the model of the body part to obtain a set of baseline impedances $\{Z_1, Z_2, \dots, Z_{n_{cl}}\}$ where Z_i is the impedance associated with the i^{th} electrode pair.

17. The method of claim 16, wherein the step of computing a diagnostic includes

calculating an average of a function $f(Z_i, Z_i^M)$ at the k^{th} finite element, the average given by

$$\langle f_k \rangle = \sum_{i=1}^{n_{cl}} w_{ik} f(Z_i, Z_i^M), \text{ wherein the diagnostic at the } k^{\text{th}} \text{ finite element is}$$

defined to be $\langle f_k \rangle$.

18. The method of claim 17, wherein the function $f(Z_i, Z_i^M)$ is given by

$$f(Z_i, Z_i^M) = \frac{Z_i}{Z_i^M} .$$

19. The method of claim 17, further comprising

obtaining diagnostics at each of the other finite elements, wherein the step of utilizing the diagnostic includes

averaging the diagnostics at each of the finite elements to find an averaged diagnostic $\langle f \rangle$; and

calculating a second averaged diagnostic, $\langle f_{\text{homo}} \rangle$, corresponding to a homologous body part.

20. The method of claim 19, wherein the step of utilizing the diagnostic further includes calculating a difference $\langle f \rangle - \langle f_{\text{homo}} \rangle$, wherein the quantity $|\langle f \rangle - \langle f_{\text{homo}} \rangle|$ is indicative of the possibility of disease in the body part or the homologous body part.

21. The method of claim 19, wherein the step of utilizing the diagnostic further includes calculating a quantity

$$\frac{\langle f \rangle - \langle f_{\text{homo}} \rangle}{\frac{1}{2}(\langle f \rangle + \langle f_{\text{homo}} \rangle)}$$

that is indicative of the possibility of disease in the body part or the homologous body part.

22. A system for diagnosing the possibility of disease in a body part, the system comprising

a grid module for representing the body part with a grid having a plurality of finite elements;

a weight module for using a model of the body part to compute a set of weights associated with a particular one of the plurality of finite elements; and

a diagnostic module for computing a diagnostic at the particular finite element to diagnose the possibility of disease in the body part, wherein the diagnostic is a function of the set of weights, and a measured electrical property of the body part obtained with an electrode array.

23. The system of claim 22, wherein the grid module also obtains a baseline electrical property associated with the body part using the model thereof, the diagnostic being a function of the baseline electrical property, the set of weights, and the measured electrical property of the body part obtained with the electrode array.

24. The system of claim 22, wherein the grid module also conditions the measured electrical property to compute the diagnostic.

25. The system of claim 22, wherein the measured electrical property is an impedance.

26. The system of claim 22, wherein the grid is two dimensional.

27. The system of claim 22, wherein the grid is three dimensional.

28. The system of claim 22, wherein the model of the body part is a physical model.

29. The system of claim 28, wherein the physical model of the body part is associated with a control subject.

30. The system of claim 22, wherein the model of the body part is a numerical model that can be analyzed using a finite element method.

31. The system of claim 30, wherein the numerical model assumes a non-uniform resistivity.

32. The system of claim 22, further comprising an electrode array for obtaining the measured electrical property of the body part.

33. The system of claim 32, wherein the electrode array includes
 n_{CI} current injection electrode pairs to apply on the body part, where n_{CI} is an integer greater than zero; and
 n_{CV} voltage measurement electrode pairs to apply on the body part, each of the current injection electrode pairs associated with one of the n_{CV} voltage measurement electrode pairs.

34. The system of claim 33, wherein

a first pair of the n_{CI} current injection electrode pairs transmits a first current through the body part;

the voltage measurement electrode pair associated with the first current injection electrode pair measures the resultant voltage difference V_1^M ; and

the other electrode pairs inject and measure to obtain all n_{CI} voltage differences, $\{V_1^M, V_2^M, \dots, V_{n_{CI}}^M\}$.

35. The system of claim 34, further comprising an impedance measuring instrument for measuring a set of impedance measurements $\{Z_1^M, Z_2^M, \dots, Z_{n_{CI}}^M\}$ using the n_{CI} voltage differences, Z_i^M being the measured impedance associated with the i^{th} voltage electrode pair.

36. The system of claim 35, wherein the grid module includes

a finite element analysis module, which employs conditions corresponding to the injections of the currents between the pairs of current injection electrodes, to calculate an electrical potential as a function of position on the grid; and

a gradient module for using the electrical potential near the k^{th} finite element to compute a set of current densities, $\{J_{1k}, J_{2k}, \dots, J_{n_{CI}k}\}$, where J_{ik} is

the current density at the k^{th} finite element when current is injected between the i^{th} current injection electrode pair, wherein the set of weights are calculated according to

$$w_{ik} = \frac{J_{ik}}{\sum_{j=1}^{n_{CI}} J_{jk}}$$

37. The system of claim 36, wherein the grid module uses the model of the body part to obtain a set of baseline impedances

$\{Z_1, Z_2, \dots, Z_{n_{CI}}\}$ where Z_i is the impedance associated with the i^{th} electrode pair.

38. The system of claim 37, further comprising

an averaging module for calculating an average of a function $f(Z_i, Z_i^M)$ at the k^{th} finite element, the average given by

$$\langle f_k \rangle = \sum_{i=1}^{n_{CI}} w_{ik} f(Z_i, Z_i^M), \text{ wherein the diagnostic at the } k^{\text{th}} \text{ finite element is}$$

defined to be $\langle f_k \rangle$.

39. The system of claim 38, wherein the function $f(Z_i, Z_i^M)$ is given by

$$f(Z_i, Z_i^M) = \frac{Z_i}{Z_i^M}.$$

40. The system of claim 39, wherein

the electrode array, the grid module and the weight module are used to calculate diagnostics at the other finite elements, which together with the particular one, comprise the plurality of finite elements; and

the diagnostic module averages the diagnostics at the finite elements to find an averaged diagnostic $\langle f \rangle$, and calculates a second averaged diagnostic, $\langle f_{\text{homo}} \rangle$, corresponding to a homologous body part.

41. The system of claim 40, wherein the diagnostic module calculates a difference $\langle f \rangle - \langle f_{\text{homo}} \rangle$ that is indicative of the possibility of disease in the body part or the homologous body part.

42. The system of claim 40, wherein the diagnostic module calculates a quantity

$$\frac{\langle f \rangle - \langle f_{\text{homo}} \rangle}{\frac{1}{2}(\langle f \rangle + \langle f_{\text{homo}} \rangle)}$$

that is indicative of the possibility of disease in the body part or the homologous body part.